IRRIGATION.

[A paper read before the New Hampshire Board of Agriculture, at a meeting holden at the Agricultural College, in Hanover, on the 23d day of October, 1877, by J. B. Walker, of Concord.]

Tant vaut l'homme, tant vaut le pré.

—*Old Proverb, as quoted by M. Vidalin.*

The presence of moisture in the soil is one of the indispensable conditions of successful vegetation. Without it, the buried seed cannot germinate ; without it, the growing plant, from seventy to ninety-five per cent. of which is water, withers and dies. Vast areas upon the world's surface, which are rich in all the elements of plant-food, are to-day, and some of them have ever been, barren wastes, simply from the want of moisture. The arid plains lying west of our one hundredth meridian, and rising to the eastern foot hills of the Rocky Mountains, with those of south-eastern California and Peru, in this hemisphere, as well as the vastly larger deserts of northern Africa and Arabia in the Eastern, are made sterile by the perpetual aridity which rests like a curse upon them.

Other extensive areas, partially but insufficiently watered, are of uncertain productiveness. The southern part of the great Valley of California can be relied upon to produce crops two years only in every five. The summer rain-fall in New England is rarely equal to the production of maximum crops. The personal experience of almost every observing farmer will attest the truth of this last statement. I have repeatedly had my hay crop cut short twenty-five per cent. by drouth. More or less of you have doubtless suffered in the same way. Four fields, which this year gave me about one hundred tons of English hay, produced but a little more than eighty in 1876, the difference of yield being mainly due to the different amounts of moisture afforded by the two seasons.

In 1870, the hay crop of this state was six hundred thousand tons (612,648), and worth, at ten dollars per ton, about six millions of dollars ($6,126,480). The diminution of this sum, by drouth, to the amount of twenty-five per cent., would consequently inflict upon our farmers a direct loss of more than a million and a half of dollars ($1,531,621). If to this there be added a similar one upon their corn, rye, oats, wheat, and potatoes, the aggregate will reach two millions and a half of dollars ($2,511,921) upon these six staples alone. Such losses we are continually encountering, and they are largely due to the want of sufficient moisture in the soil during the periods of vegetation. Many of the most distressing famines of which we read in sacred history, as well as in that of modern times, were caused by protracted drouths.

But what nature has thus withheld, man has oftentimes supplied and found in irrigation, or the artificial watering of ground, a remedy for drouth and all its attendant evils. Although new to us, it is one of the oldest practices of husbandry. We find mentions of it in authentic records all the way back to ages very remote.* Moses, in his grand charge to his people, nearly fifteen centuries before the time of our Saviour (B. C. 1451), said to them, regarding the Promised Land, it "is not as the land of Egypt, from whence ye came out, where thou sowedst thy seed, and *wateredst it with thy foot.*" † A thousand years later, Herodotus said,—"The whole of Babylonia is, like Egypt, intersected with canals.‡ And still later, in the Augustan age, the graceful Latin poet, who has embalmed in his immortal verse as well the peaceful works of husbandry as the valiant deeds of arms, closes his delightful narrative of the contest between Damœtas and Me-

* "There are, in ancient Armenia, extensive districts which were already abandoned to desolation at the earliest historical epoch, but which, in a yet remoter antiquity, had been irrigated by a complicated and highly artificial system of canals, the lines of which can still be followed; and there are in all the highlands where the sources of the Euphrates rise,—in Persia, in Egypt, in India, and in China,—works of this sort, which must have been in existence before man had begun to record his own annals."—*Marsh's "The Earth, as Modified by Human Action,"* p. 449.

† Deuteronomy, chapter xi, verse 10.

‡ Herodotus (edition of D. Appleton & Co., 1859), vol. i, p. 257.

nalcas by a pleasing figure drawn from the irrigation of his day,—"*Claudite jam rivos, pueri, sat prata biberunt.*"*

The abundant literature of the subject, found in most of the languages of Europe, from Virgil's time down to our own, afford direct proof of its extensive practice during the last two thousand years.†

The functions of water in the maintenance of vegetation are both chemical and physical. It supplies, in its elements, large quantities of oxygen and hydrogen to growing plants. It combines chemically with the carbon of the carbonic acid present within their structures. It serves as the vehicle of their circulation, and conveys in solution to their digestive organs the earth-food upon which they are in part built up.

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* Virgil's Bucolics, Eclogue 3d, line 111.

† "The extent to which irrigation is carried on, in these glens and valleys [of Norway], shows a spirit of exertion and coöperation to which the latter can show nothing similar."—*Laing, as quoted by H. Fawcett, Political Economy*, p. 186.

"Some idea of the extent of the artificially watered soil of India may be formed from the fact that, in fourteen districts of the Presidency of Madras, not less than 43,000 reservoirs, constructed by the ancient native rulers for the purpose of irrigation, are now in use, and that there are in those districts at least 10,000 more, which are in ruins and useless.

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"The cultivable area of Egypt, or the space between desert and desert where cultivation would be possible, is now estimated at ten thousand square statute miles. Much of the surface, though not out of the reach of irrigation, lies too high to be economically watered, and irrigation and cultivation are therefore at present confined to an area of seven thousand square miles, nearly the whole of which is regularly and constantly watered when not covered by the inundation, except in the short interval between the harvest and the rise of the waters. For nearly half the year, then, irrigation adds seven thousand square miles to the humid surface of the Nile valley, or, in other words, more than decuples the area from which an appreciable quantity of moisture would otherwise be evaporated; for after the Nile has retired within its banks, its waters by no means cover one tenth of the space just mentioned.

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"There are few things in European husbandry which surprise English or American observers so much as the extent to which irrigation is employed in agriculture, and that, too, on soils and with a temperature where their own experience would have led them to suppose it would be injurious to vegetation, rather than beneficial to it. In Switzerland, for example, grass-grounds on the very borders of the glaciers are freely irrigated, and on the Italian slope of the Alps, water is applied to meadows at heights exceeding 6,000 feet.

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"Arrangements are concluded, and new plans proposed, for an immense increase of the lands fertilized by irrigation in France and in Belgium, as well as in Spain and Italy; and there is every reason to believe that the artificially watered soil of the latter country will be doubled, and that of France quadrupled, before the end of this century."—*Marsh's Earth*, pp. 452, 453, 456, 459.

Its vast importance is clearly evinced by the amount of it which they exhale. Prof. Johnson says, that "Schleiden found the loss of water from a square foot of grass sod to be more than one and a half pounds in twenty-four hours." We also have it, upon pretty good authority, that a ton of hay exhales while growing two tons and a half of water.

It has been found by actual experiments with wheat, by Mr. Lawes, of Rothampstead, in England, that, for every pound of dry matter produced, two hundred pounds of water was evaporated; and that, for every pound of mineral matter assimilated by the crop, two thousand pounds passed through the plant.* M. Harvey Magnon has shown that, in the Vosges, water is sometimes applied in successive irrigations to a depth of five hundred and eighty-eight feet per annum.

The frequent drouths, which occur during the periods when vegetation should be most active, the porous character of granitic soils, and an insufficient supply of fertilizers render this subject of irrigation one of practical importance to the New Hampshire farmer, and one to which he will do well to give some attention. It has already awakened much interest in California, Colorado, and Utah, while in southern Europe, Egypt, eastern Turkey, and northern India, it is as much a common practice in farming as is manuring, ploughing, or weeding.

A hope that the effort may not be altogether uninteresting or

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* "Table showing the total quantity of water evaporated, and the grain produced; also, the quantity of water consumed for one pound of grain in nine experiments with various fertilizers:

	Pounds of water evaporated.	Pounds of grain produced.	Pounds of water for one pound of grain.
No. 1	1,616	.6	2,693
No 2	1,512	.8	1,890
No. 3	4,703	2.4	1,960
No. 4	2,202	2.7	816
No. 5	3,262	2.9	1,125
No. 6	4,327	3.1	1,396
No. 7	4,751	5.5	864
No. 8	7,417	9.2	806
No. 9	7,702	10.6	727

—*Stewart's Irrigation*, p. 12.

profitless, induces the presentation to you, at this time, of some of the more salient facts embraced in the great irrigating system of northern Italy,—facts derived by the speaker, in part, from personal observation upon the ground, and in part from a consultation of some of the best authorities upon the subject within his reach. Nowhere in the world, unless, perhaps, in northern India, can one study the subject of irrigation under more favorable circumstances than in the valley of the Po, where long experience, aided by science, has tested its practices, and where nature has lavishly furnished all things necessary for its highest success.

THE GREAT PLAIN OF LOMBARDY AND PIEDMONT.

The great plain of Lombardy and Piedmont, in northern Italy, sometimes called the valley of the Po, is about two hundred miles long, with an average width of some fifty or sixty. It extends from the foot hills of the main Alpine chain on the north, to those of the Apennines on the south, and from the base of the Maritime Alps on the west, nearly or quite to the head of the Adriatic, having an area of 14,511 square miles,* or 9,287,040 acres.

It is cut into two unequal parts by the Po, which flows through it from west to east, leaving by far the larger and more important one on the north of it. This has two general inclinations,—one southerly, of from three to twelve feet per mile, to the river, and another, less marked, from west to east, corresponding to the river's fall. Its outer edges are serrated, extending in points up into the valleys of the surrounding mountains.

ITS LATITUDE AND TEMPERATURE.

Its latitude is about that of the southern half of New England, and it has an average rain-fall of some thirty-seven inches, with a mean temperature ranging, during the ordinary irrigating season, which begins in March and ends in September, from forty-five to seventy-five degrees Fahrenheit.

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*It may be interesting to remember that New Hampshire has an area of 9,280 square miles, or 5,939,200 acres.

ITS SOIL.

The soil of this great plain varies in character, but is generally a light sand underlaid by deep strata of gravel. Limited sections, however, are clay, similarly underlaid.

ITS WATER-SHEDS.

A very important characteristic of this plain is found in the immense water-sheds inclining to it from the south, west, and north. The latter, which is far the largest, stretches along its entire length, extending from its northern border to the summit line of the main Alpine chain, and having an area of some 5,000 square miles. Along this lofty line rises a succession of sublime summits, which, piercing the snow-line, render constant in their flow the streams which drain it.*

Among these towering crests we find Mont Viso, 12,586 feet; Mont Genèvre, 11,785 feet; Mont Cenis, 11,457 feet; Mont Blanc, 15,750 feet; Great St. Bernard, 11,080 feet; the Matterhorn, 14,710 feet; Mont Rosa, 15,157 feet; the Simplon, 10,600 feet; and Mont Saint Julien, 13,850 feet, respectively, in height.

ALPINE STREAMS.

The streams which collect the drainage of this vast water-shed are numerous, and some of them exceedingly violent, bearing within and upon their swift currents large quantities of sand, stones, and other mountain débris. Were they to continue onward to the plain with unabated rapidity, they would furrow its fair surface with destruction, and ruin it for human occupancy.

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* "The advantage of permanency of supply during the season of irrigation is secured most satisfactorily to the country on the left bank of the Po, as the whole of the great rivers which traverse it rise within the regions of perpetual snow. During the month of March, the influence of the increasing temperature becomes perceptible. The streams, which during the winter had shrunk to their smallest dimensions, then begin to increase in volume, and they go on augmenting during the successive summer months, slowly and steadily, until they attain their maximum, in August, after which, as the temperature falls, they gradually return to their winter channels. Of course, both in winter and in summer, floods, ordinary and extraordinary, are constantly occurring; but, viewed in relation to agriculture, it is the constant and unvarying influence of the solar heat on the snows that gives to the rivers flowing from them their true value."—*R. Baird Smith's Italian Irrigation*, vol. i, p. 85.

LAKES.

Providence, however, has opposed a sure barrier to such a calamity, and placed a series of lakes just where the mountains lose themselves in the plain. These, known generally as the Italian lakes, serve the double purpose of arresting the mad flow of these furious streams, and of precipitating into their vast depths the impurities suspended in their waters.

There are eleven of these lakes, some of which possess more general interest on account of the romance attaching to them, than as reservoirs of supply for one of the grandest irrigating systems which the world has ever seen. Lakes Maggiore, Lugano, Como, Sabino, and Garda are the most important. The first has an area of 47,280 acres, and a maximum depth of 2,624 feet,* and the latter an area of 73,856 acres, and a depth of 1,915 feet. The aggregate area of the eleven amounts to nearly two hundred thousand acres (195,888).

The following table gives the several names, areas, and depths of these eleven lakes:

Names.	Areas.	Maximum depth.
Maggiore	47,280 acres.	2,624 feet.
Lugano	12,800 "	520 "
Como	34,914 "	1,928 "
Sabino	14,720 "	984 "
Garda	73,856 "	1,915 "
Varese	3,840 "	85 "
Comabio	960 "	35 "
Pusiano	1,664 "	100 "
Oggiono	1,728 "	50 "
Spinone	640 "	
Idro	3,456 "	400 "
	195,888 acres, or 306 square miles.	

Their large area and great depths render these lakes of vast consequence as purifiers and regulators in the distribution of the waters of this immense slope. They rise and fall but little throughout the year, the gradual melting of the ice and snow of the higher

* Lake Winnepiseogee, in New Hampshire, has an area of 44,672 acres, and its maximum depth does not exceed two hundred feet.

altitudes in summer preserving the equableness of their volumes.*

RIVERS.

The more important rivers originating in the overflow of these great reservoirs are the Ticino, flowing from Lake Maggiore, the Adda from Lake Como, the Oglio from Lake Iseo, the Chiese from Lake Idro, and the Mincio from lake Garda. These afford an aggregate discharge of 25,525 cubic feet of water per second.

The following table gives the number of cubic feet per second severally discharged by these rivers:

NAMES.	Cubic feet.
Ticino	11,667.55
Adda	6,932.45
Oglio	2,975.35
Chiese	1,291.50
Mincio	2,658.95
Total discharge	25,525.80

There are also others of lesser volumes, like the Dora Repaira, the Stura, the Orco, the Dora-Baltea, the Sesia, the Agogna, the Terdoppio, the Brembo, the Serio, the Mella, and the Clisio,—some derived from small lakes, but most from springs and mountain rills. These, with the "Fontanili," suffice to about double the aggregate above mentioned, making the whole supply of this water-shed nearly 47,000 cubic feet per second, or some fifteen or sixteen times that of the Merrimack in New Hampshire. The supplies afforded by the water-sheds of the west and south are small compared with this, and their further consideration need not detain us.

*Capt. Smith says of Lago Maggiore,—"The greatest fall of surface-level of the water below its ordinary height, in times of extreme dryness, has been noted as 5.76 feet. The floods to which in spring and autumn the lake is subject, rise generally about 7 feet above the ordinary level of the surface." The same author also remarks, in relation to Lago di Garda,—"The extreme fall of the surface-level in times of the greatest dryness is only 1.64 feet. The usual floods rise only 3.28 feet above low-water mark, or 1.64 feet above the ordinary level of the water."

FONTANILI.

The Fontanili just alluded to, which furnish in the aggregate about 3,000 cubic feet of water per second, are springs found at different localities in the water-bearing strata of the plain. Indications of their presence, apparent to experts, lead to their discovery, and they are made available by excavations, generally of from nine to fifteen feet in depth. Their waters are collected by wooden tubes inserted in the ground at the bottom of the openings. Thence, they are conveyed by aqueducts to lower levels, where their use becomes practicable.

It often happens, therefore, that Fontanili on one estate are owned by the proprietors of another, quite distinct, and upon whose land their waters may be made available.

Many canals cut in the water-bearing strata of the plain are often, in part, furnished with water by these springs, sometimes receiving as much as one half of their entire supply from them. The Fontanili between the rivers Sesia and Ticino afford water to ninety-four small canals, having an aggregate length of 467½ miles, and which irrigate 52,500 acres of land, thereby increasing its annual rental £30,000.

Different Fontanili vary greatly in the amounts of water which they severally afford, like springs elsewhere. As the perpetual right to a single cubic foot per second sells for the sum of £280, their value is apparent. An eminent English hydraulic engineer speaks of one yielding twelve cubic feet per second, which, at this rate, would be worth £3,360, and says that the whole amount of water thus derived is valued at £840,000, or $4,200,000.

Coming from considerable depths below the earth's surface, their waters are warmer in winter than those of rivers and lakes, and for that reason are most highly esteemed for the watering of "marcite," or winter meadows. In fact, these are very largely dependent upon them for their irrigation.

CANALS.

The water thus supplied is taken to different parts of the country by canals. These are of various lengths and volumes. Capt. R. Baird Smith, the writer just referred to, and the author of the very able work on Italian Irrigation, to which we have before referred, after carefully describing many of these, asserts that the trunk and branch canals, in Piedmont alone, have an aggregate length of 1,275 miles, and afford an aggregate supply of 8,290 cubic feet of water per second. He also states, after presenting details relative to those in Lombardy, that their aggregate length is 4,500 miles, and their aggregate supply 15,118 cubic feet per second. These, having a total length of 5,575 miles, and a supply of 23,408 cubic feet per second, together with some others of less importance, irrigated, at the time he wrote—some twenty years ago—1,596,105 acres, being somewhat more than one sixth of the entire area of Lombardy and Piedmont.*

Some of these canals possess considerable historic interest, and are quite ancient. The Naviglio Grande was constructed as far back as 1178, the Canal Muzza in 1220, the Gattinara in 1320, and the Canal del Rotto in 1350. These, as well as others that might be mentioned, were all in use before Columbus, who was born just across the Maritime Alps, at Genoa, discovered our continent.

Leonardo da Vinci, whose immortal painting of the Last Supper may still be seen upon a wall of the old refectory of the suppressed monastery of Sta. Maria delle Grazia, at Milan, ranks as high among the hydraulic engineers of Italy as he does among her painters. He was ducal engineer to Francesco Sforza I, at the close of the fifteenth century (1498), and to him Milan is indebted for the system of locks, which, through the Naviglio Interno, united the Canal Martesana with the Grand Canal, and joined the Adda to the Ticino, thereby connecting Lake Como with Lake Maggiore, and securing to that city water communication with both.

Some five hundred and fifty years have been spent in the completion of this great system of canals. They have been constructed by various parties,—some by former governments of Piedmont and Lombardy, some by municipalities, others by religious houses and corporations, and others still by individuals.

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* Mr. George P. Marsh gives the area of irrigation in Italy as 2,250,000 acres, equal to about four fifths of that of the land devoted to farms in Massachusetts.

Hardly any of them yield fair returns upon their cost, the income of those in Piedmont not exceeding four per cent.

This unprofitableness is due, in a great degree, to the fact that grants in perpetuity of their waters to riparian landlords have reduced very largely their gross income without diminishing at all the expense of their maintenance. As an instance in point, the writer of this paper was told by the occupant of a large farm, near Milan, that he paid nothing for the large amounts of water used in its irrigation, as all necessary water rights had been secured in perpetuity by some one or more of its landlords years ago. In fact, the current income of some canals hardly suffices to defray the expenses of their maintenance, and that, notwithstanding they furnish in addition to water for irrigation considerable motive power to mills, and to highways for transportation.

The money received, centuries ago, perhaps, for these perpetual water grants, was in part expended in their construction, while much of it, doubtless, has been squandered. In many cases, also, during troublous times, valuable grants were probably made, to landlords of overshadowing power, for inadequate and sometimes without any actual compensation.

But persons conversant with the returns of our own "Grand Canal," in New York, should not wonder at the meagre income of these Italian canals, which have run the gauntlet of mismanagement for half a dozen centuries, encountering repeated revolutions in governments, the rapacity of powerful landlords, and the general insecurity and mismanagement of all things, much of the time prevailing. We cannot, however, but note that these returns are in marked contrast with the twenty-four to thirty-six per cent. yielded by some of the irrigating canals of northern India.

But it should not be forgotten that an indirect benefit has come from them which does not appear in their annual returns. I allude to the increased rental which irrigation has produced. The total of this, in Piedmont and Lombardy, is estimated at $4,150,000 per annum, an addition of nearly three dollars per acre to the yearly value of the land previous to its irrigation.

INTRICACY OF THE SYSTEM.

The vast net-work of these canals, branches, minor streams, and distribution channels appears to the passing traveller intricate almost beyond comprehension. A plan of those which furrow in all directions the country south of Milan, between the Adda, the Po, and the Ticino, resembles more one of the bewildering charts seen upon the walls of a medical lecture-room, and used to display the coursings of the nerves, arteries, and veins of the human body, than any other object that occurs to us.

DISTRIBUTION.

From the canals the water is taken by smaller channels to all parts of the neighboring country. The systems of distribution vary to suit the needs of particular crops,—rice, for instance, requiring a mode of application different from that demanded by grass; and Indian corn still another, unlike either.

PREPARATION OF GROUND.

We have not time to describe this, and can only say, in passing, that the ground must be carefully prepared by grading, ploughing, channelling, etc., previous to its irrigation. This oftentimes requires much skill and large expense.

Such estimates as I have been able to obtain place the ordinary cost of the preparation of marcite meadows at amounts varying from seventeen dollars and fifty cents to thirty dollars per acre. It is often much greater. Without some preparation, irrigation is impracticable, and never attempted; for this is absolutely essential to its success.

MEASUREMENT OF WATER.

The water used in Italian irrigation is measured and sold by the number of cubic feet per second furnished to the purchaser. An average price for one cubic foot per second in perpetuity is about fourteen hundred dollars, or eighty-four dollars per annum, reckoning the interest of the money thus invested at six per cent. The annual expense per acre varies greatly, according to the requirements of the different crops to which it is applied.

COST OF WATER PER ACRE.

One cubic foot of water per second suffices for the irrigation of one hundred and eighty acres of Indian corn. It is applied once a month to a depth of 3.93 inches, making an aggregate of 23.58 inches for the season, at an expense of eighty-four cents per acre; and the ordinary yield of this grain is fifty bushels per acre.

The same quantity suffices for ninety acres of summer meadow, and is applied three times each month to a depth of 2.34 inches at a watering, making an aggregate of 42.12 inches for the season, at an expense of one dollar and thirty-eight cents per acre, the average yield being about twenty-five thousand pounds (25,088) of green grass per acre.

A crop of rice requires one cubic foot per second for every forty acres, to be applied in one hundred waterings, each of sixty-two one hundredths of an inch in depth, aggregating sixty-two inches for the season, at an expense of three dollars and forty-eight cents per acre. The usual yield is about eighteen bushels (17.8) per acre.

On winter meadows, one cubic foot per second suffices for but three acres. These are irrigated daily to a depth of nearly eight (7.92) inches, the application for the season of about five months amounting to eleven hundred and eighty-eight inches, or ninety-nine feet. The grass upon this is cut every forty-five days, and affords a total yield of fifty thousand (50,400) pounds per acre, grown at an expense for irrigation of five dollars.

The following table, taken from Capt. R. Baird Smith's valuable work, presents these facts more in detail:

NUMERICAL DETAILS CONNECTED WITH THE EMPLOYMENT OF WATER FOR IRRIGATION IN THE AGRICULTURE OF NORTHERN ITALY.

	Number of acres irrigated by 1 cubic foot per second.	No. of waterings.		Depths of strata of water.			Price of irrigation per acre.	Produce in grass or grain per acre.	Net value of produce per acre.
		During the mo.	During the season.	Each watering.	Monthly.	For the season.			
				inch's	inch's	inch's	s. d.	cwt.	
Summer meadows,	90	3	18	2.34	7.02	42.12	5–9	224	£3½ to £4
Winter meadows,	3	30	150	7.92	237.06	1,188	21–0	450	7 to 12
								bush.	
Rice,	40		100	.62		62	14–6	17.8	5 to 7
Indian Corn, Flax, &c.,	180	1	6	3.93	3.93	23.58	3–6	50	2 to 3

Irrigation is applied to nearly all farm crops, as well as to vines and trees generally, in connection with manures, but sometimes without them.

The irrigating season begins on the 25th day of March, and ends on the 8th day of September. That of the *marcite,* or winter meadows, however, begins at the close of the ordinary season, and occupies the period intervening between that time and the 25th day of the following March.

Crops produced by irrigation, except those of grass, are somewhat inferior in quality to those raised by dry culture; but the great benefits otherwise resulting therefrom render this consideration an unimportant one.

Where the facilities for irrigation are general and extensive, there exists a marked tendency to large estates and sparser populations than are found where its practice is restricted. This fact becomes immediately apparent, upon comparing the number of people per square mile upon the lower with that found upon the upper sections of the great plain.

In Lombardy, and I presume the same may be the case in Piedmont, the land is generally held in large tracts by landlords, who rent it in convenient portions to tenant farmers, under one of three different forms of lease. A distinguishing feature of the first of these is, that the rent is payable in money; of the second, that it is payable in wheat; while under the third, the *metayer* or share system prevails, the annual products being divided upon some established basis between the landlord and his tenant. At the same time, there are sections where tenancy and proprietorship unite in the same individual, and there communities of peasant freehold farmers may be found.

Terminating here this imperfect sketch of Italian irrigation, I will devote a portion of my remaining time to a very brief consideration of the common methods employed for the distribution of water by irrigation. From a practical point of view, next in importance to its actual supply is an accurate knowledge of the best systems of its application to the soil.

Long experience in the old world has settled upon some three or four distinct plans, as, on the whole, the most practicable, and the best. These have been subjected to endless modifications of detail, but will, upon close inspection, resolve themselves into one or another of the small number just named.

They are designated, generally, as,—

1st. Irrigation by inundation.

2d. Irrigation by inclined planes *(en plan incliné)*.

3d. Irrigation by parallel beds *(en ados)*.

IRRIGATION BY INUNDATION.

The occasional overflows of our streams, in times of freshet, upon the grounds through which they pass, afford an idea of this kind of watering, and of its benefits. Some of us, perhaps, have our grass-crops doubled through this agency, and some, possibly, may possess meadows whose perpetual fertility is insured thereby. Few grounds, however, are so situated as to be within the reach of such flowage, which, valuable though it be, is generally uncertain and beyond control.

But larger areas by far exist, upon or near sufficient streams, which, by the aid of a little art, may be subjected to inundations nearly or quite as valuable, and which can be introduced or withdrawn at will. The diagram below, Fig. 1, taken from the Culture Générale of Lefour represents such a tract, and the manner of watering it.

The lines C D and E F mark the sides of a plain, situated between hills, inclining to it on two sides. Its surface, not quite level, inclines from C E towards D F. A is a pond, which supplies

Fig. 1.

the stream A G flowing through it. The dotted lines B B B represent low dykes of earth covered with turf, and stretching across the meadow to the hills on either side of it, and dividing it into three separate compartments. The dyke at the lower end of each is high enough to secure the flooding of its entire area. A passageway for the stream, cut in each dyke where this intersects it, at B B B, is provided with a gate, which can be opened or shut at will. Any compartment, therefore, may be flooded, by closing the gate upon its lower side. In fact, any one or all may be submerged, or left dry, by simply opening or closing their lower gates. In any event, the surplus water takes care of itself by overflowing the retaining gates, and passing into the stream below. The lateral ditches branching from each side of the supply channel A G, to aid alternately the flooding and drainage, may be introduced or omitted in practice as circumstances may require.

Fig. 2 presents another plan of inundation, devised by Schwertz, the meadow being isolated by surrounding dykes, and divided into parallel beds. F represents the stream, which, dammed at G, supplies the water; E E E E, the dykes just mentioned; A, the supply-channel; J, a sluiceway leading therefrom to the meadow, supplied with water through a gate, E, and covered by a bridge, Q; N, a drainage channel at the lower end of the meadow, guarded by a gate at H, and debouching into the stream F; L L L L L L L L, surface-drains separating the meadow into the parallel beds K K K K K K K K, and terminating in N. It is evident that, by this plan, if the stream F has sufficient fall, the meadow may be flooded at will to any depth allowed by the elevation of the water at the dam, G, and the height of the surrounding dykes. It is also plain that it may be laid bare when its submersion is no longer desirable.

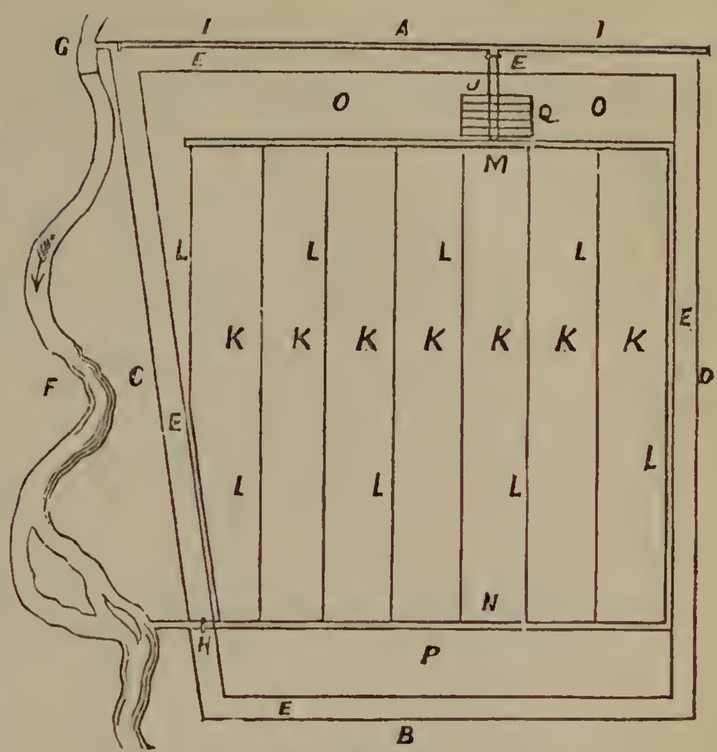


Fig. 2.

IRRIGATION BY INCLINED PLANES.

Both of the above mentioned plans provide for irrigation by submersion. Land is most commonly irrigated by passing over its surface a thin sheet of water, a part or the whole of which sinks into the soil. This purpose is often effected by means of horizontal ditches running lengthwise upon an inclined plane, and overflowing upon the slopes between them. If the plane have a regular inclination, the ditches may be made parallel to one another.

Fig. 3 presents a common plan of irrigation upon an inclined plane. I represents a stream from which a supply of water is taken by means of a canal, B, and carried along the upper side of the slope to be irrigated. Below, and parallel to it, are distributing channels, C I J K, connected with the supply canal B, and with one another by the cross channels L M N E F, running at right angles to them up and down the plane. G H represents a main drainage ditch, at the bottom of the slope, for conducting away any surplus water not absorbed by the ground above it. By means of a gate, C, at the entrance of the supply canal B, the water is let on or kept off at pleasure.

Upon irregular slopes, the distributing channels, instead of being parallel to one another, follow contour lines, and leave the intervening spaces of ground of varying widths. In other respects, the plan may be the same as the one last mentioned.

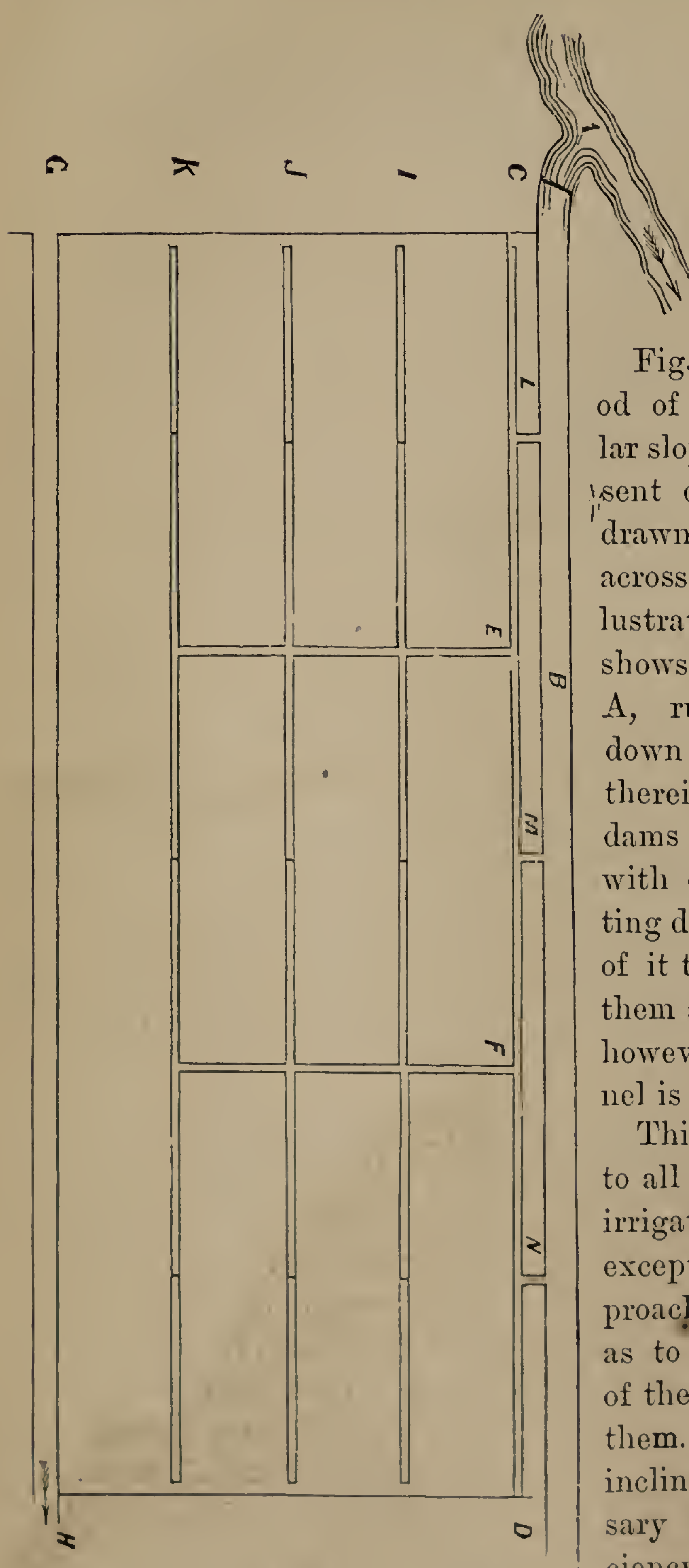


FIG. 3.

Fig. 4 shows this method of watering an irregular slope. B B B B represent distributing ditches, drawn upon contour lines across the field. The illustration here presented shows a supply channel, A, running diagonally down the hill, the water therein being arrested by dams at its intersection with each of the distributing ditches, and a portion of it thereby thrown into them at each. Generally, however, the supply channel is differently located.

This method is adapted to all surfaces upon which irrigation is practicable, except those which approach so near to a level as to prevent a free flow of the water brought upon them. A few degrees of inclination only are necessary to secure its efficiency, while upon steep mountain slopes, it is the only one that can be successfully adopted without incurring very large expense.

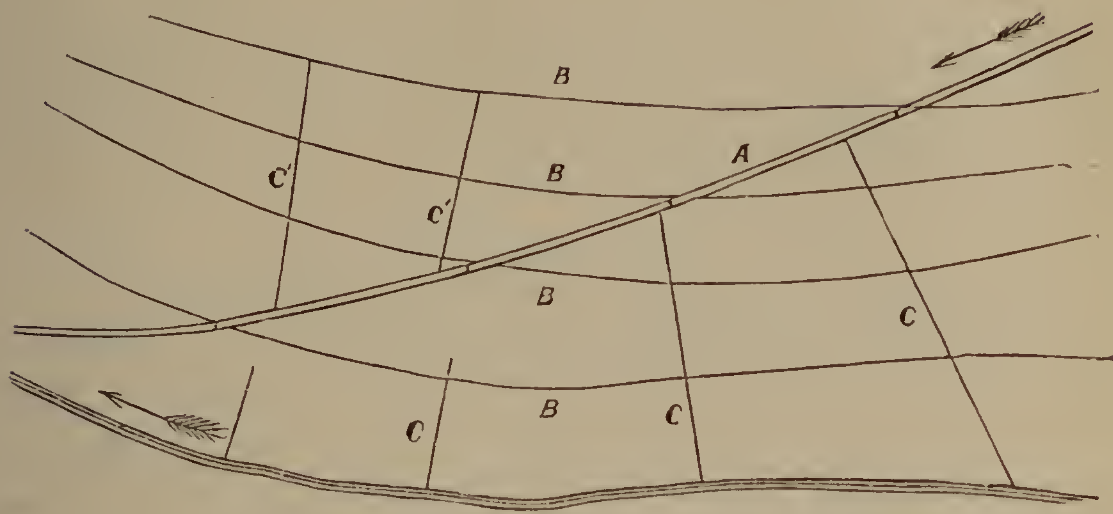


Fig. 4.

Fig. 5 shows a section of a distributing channel which can be made at little cost, oftentimes mostly by the plow. The lower bank, C, should be turfed to prevent abrasion by the water. Its width and depth will vary, of course, according to the amount of this which it is to carry.

Fig. 5.

The following drawing, Fig. 6, borrowed from the Manuel des Irrigations of Villeroy and Muller, shows at a glance how this method of irrigation may be introduced into a hilly country, and upon lands of very steep incli- nations.

A and B represent distributing channels following contour lines along the slope, and H an embankment upon the lower side, the security of which often requires care and considerable expense in its construction.

The common idea that irrigation is practicable only upon lands of moderately varying surfaces is an erroneous one.

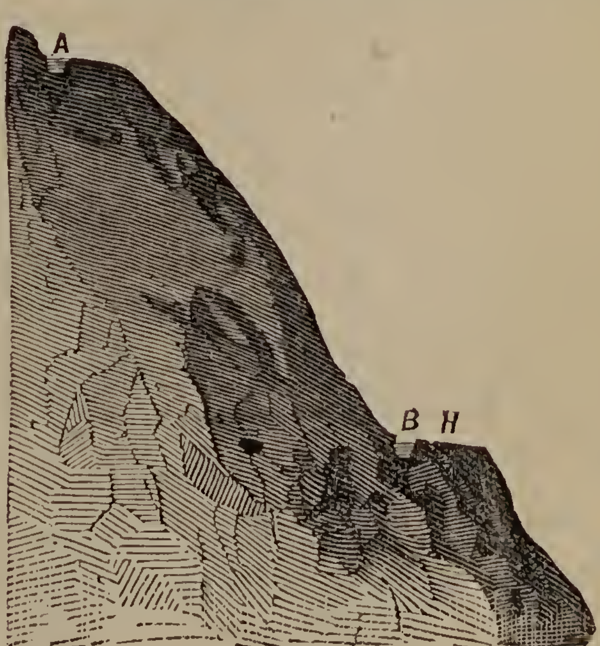


Fig. 6.

Much very successful irrigation may be found in mountainous regions upon very irregular surfaces, and often at high elevations, to which the transportation of fertilizers would be exceedingly difficult, and at times impracticable. Often has such a utilization of the water supplied by nature converted mountain wastes into fruitful fields, and been annually rewarded by luxuriant harvests.

IRRIGATION BY PARALLEL BEDS.

Irrigation by parallel beds is practicable only upon lands nearly level. It is the system adopted in the preparation of the winter meadows of Italy, already alluded to, as well as of some of the sewage meadows of England, and other European countries. The following diagram, taken from Capt. R. Baird Smith's able work on Italian Irrigation, displays clearly this system :

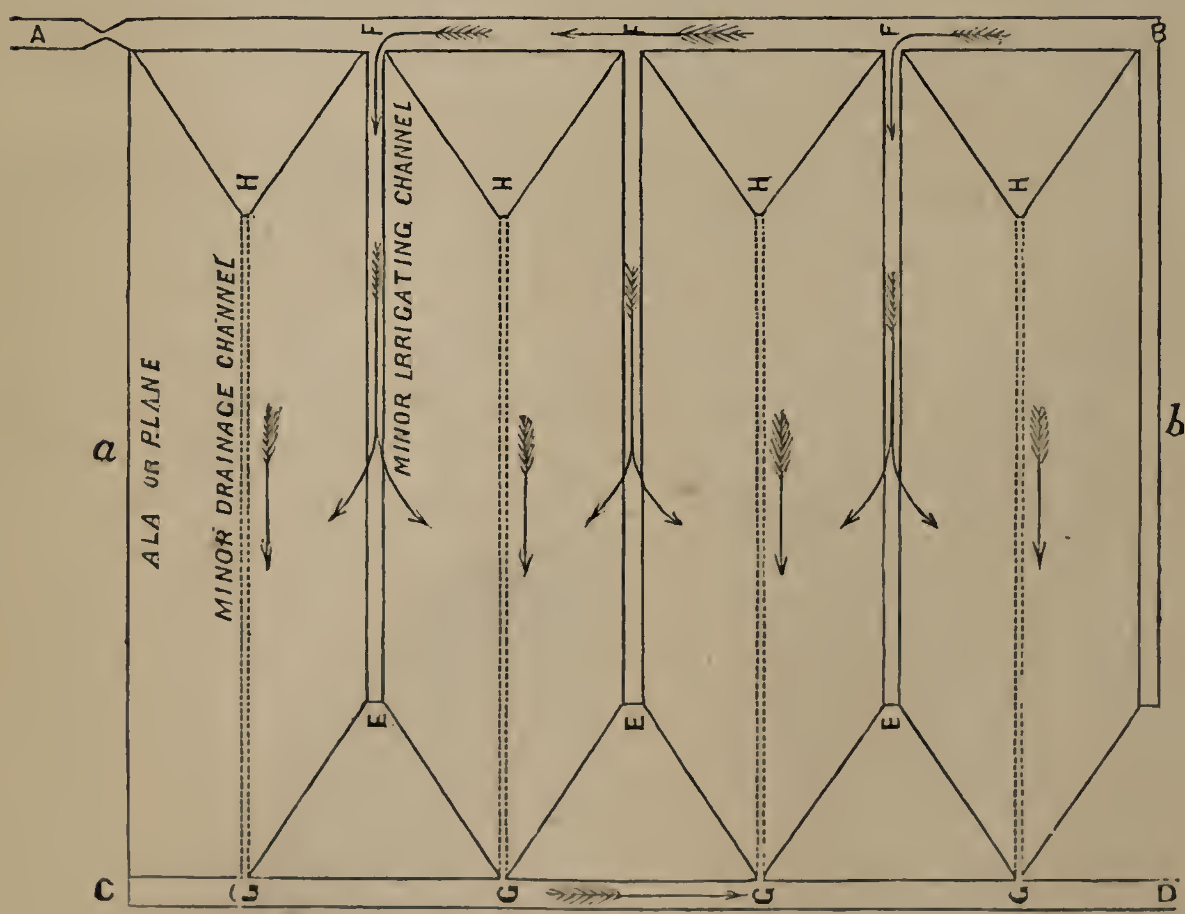


FIG. 7.

A B represents the main irrigating channel, and E F a distributing channel. C D shows the main and G H a minor drainage channel, the latter opening into the first. These minor drainage channels separate the field into parallel beds of some twenty-five or thirty feet in width, which rise from the level of the side ditches, to crest-lines, about twelve inches high. There is a gate at B to control the admission of the water: the direction of its flow is indicated by the arrows shown upon the plan. A road of convenient width for the removal of crops is usually found next the main supply and drainage channels, which crosses any minor ditches it may encounter, upon temporary bridges placed above them.

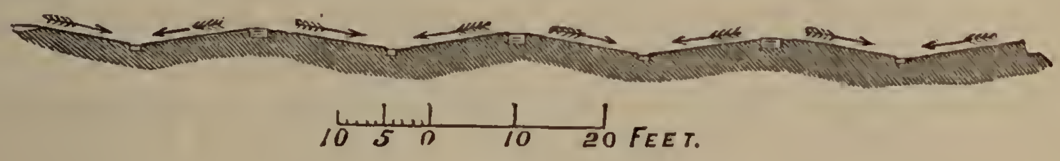


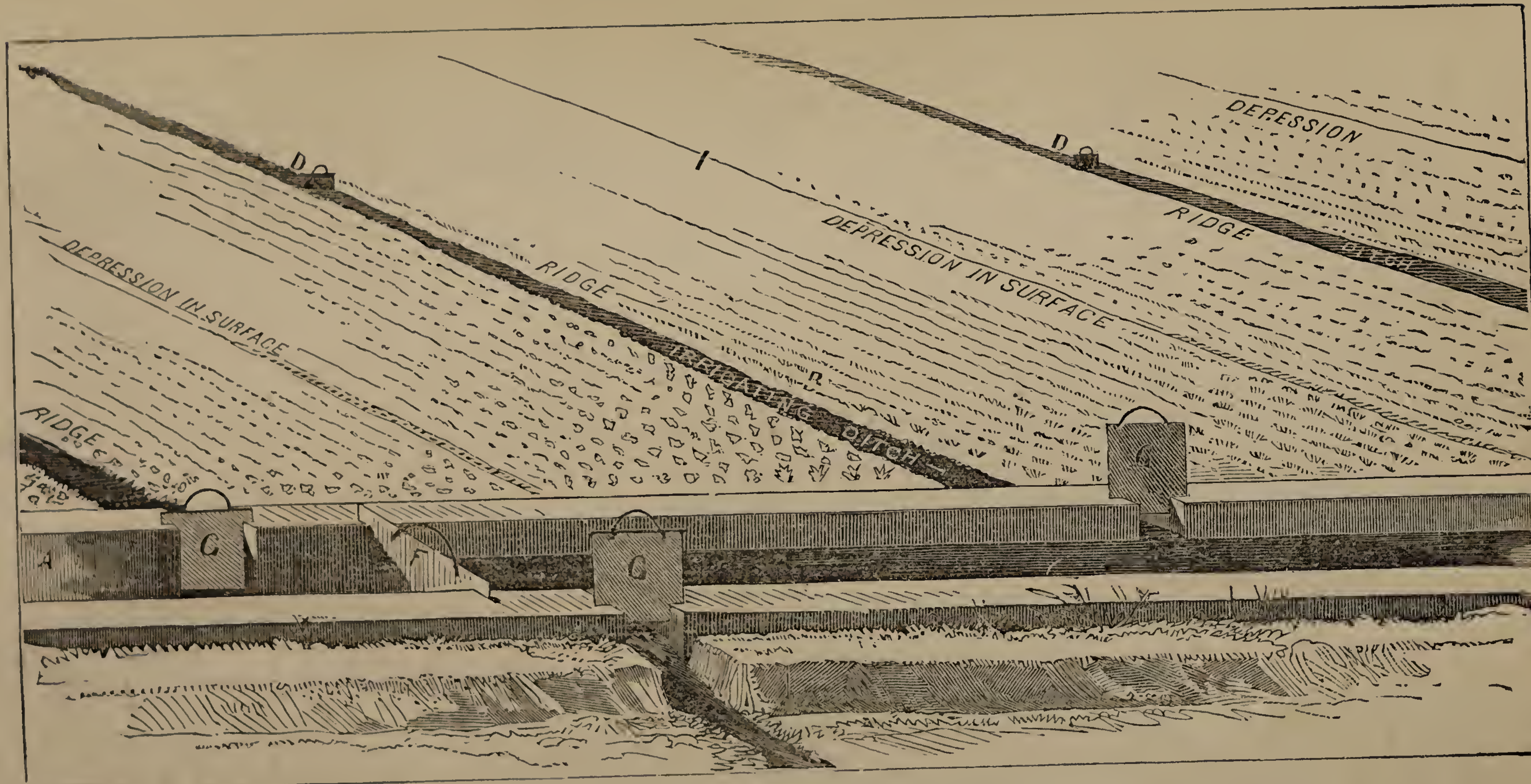
FIG. 8.

Fig. 8 gives a cross section of such a meadow, the irrigating channels being visible upon the crests of the parallel beds, and the drainage ditches in the hollows between them, while the arrows indicate the flowage of the irrigating sheets of water thrown upon their sides or wings.

Fig. 9 represents in perspective this system of irrigation. A is a main supply-channel; G G G are the gates to admit or exclude the water; D D are movable stops to arrest its flow in the irrigating ditches, and thereby produce an overflow upon each side of them.

Did time permit, we should be glad to add our testimony to the value of sewage irrigation, and enter a protest against the reckless waste of the vast quantities of fertilizing material which the sewers of our cities and large towns are daily pouring into the rivers and the seas. Our people are sending ships thousands of miles,—to Peru for guano, and to Germany for salts. With painful toil they are digging up phosphatic formations, made in some remote geologic past. To the first cost of these they are adding the large expense of their purification, and other preparation for use, while at the same time they could have for the taking, and at their own doors, immense quantities of plant-food of the richest kind, and in forms the most readily assimilable.

The writer of this paper was told, two years and a half ago, upon a sewage farm in one of the central counties of England, that was daily using the sewage of a neighboring city which had a population of 23,500, that its irrigated grass-fields yielded annually seven


DEPRESSION
D
RIDGE
DEPRESSION IN SURFACE
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DEPRESSION IN SURFACE
RIDGE
A
C
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G
G

FIG. 9.

cuttings of Italian rye-grass, each of ten tons, per acre, and that these sold readily in the field for fifteen shillings per ton.* Another farm thus fertilized, at Romford, twelve miles from London, had growing upon it, at the time of his visit, a field of mangles, nearly ready to be harvested, of forty tons per acre. Upon a third, manured by the sewage of a large asylum for the insane, was found growing, in great luxuriance, the various garden products in common use as food.

Allow me, in the few minutes that remain, to advert to some of the particular benefits of irrigation.

WATER A NUTRIMENT OF PLANTS.

Water is both a nutriment and a vehicle of it to plants. It enters them at their roots, and they can imbibe it only from the soil. The quantity they require is very great. A late writer has remarked, that the amount absorbed by an ordinary crop would cover the ground upon which it was raised a foot deep.

In many instances water may be profitably used as a substitute for other fertilizers. An enterprising farmer of Belknap county has been engaged for the last twenty years or more in raising fair crops of good stock hay by applications to his ground of water as its only manure. Another, in Merrimack county, is annually cutting two tons of good hay per acre on a meadow which, previous to its drainage and irrigation, produced only crops of wild grasses and sedges, hardly worth the harvesting. Water is the principal fertilizer he applies to it.

SECURES IMMUNITY FROM DROUTH.

Irrigation secures immunity from the disastrous drouths which are of so frequent occurrence, and places at the farmer's command the moisture essential to the production of maximum crops. It thus removes one of the most serious casualties of agriculture, insuring its highest returns, and preventing unanticipated disappointments.

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* It is stated that, in the environs of Edinburgh, poor sandy soils, not worth above twenty shillings per acre, have, by the sewage of the town, been converted into rich meadows, yielding a rent of at least twenty pounds per acre.—*Report of Mass. Board of Agriculture for 1877*, p. 177.

AERATION OF THE SOIL.

It also secures that aeration of the soil absolutely necessary for successful vegetation. The water thus applied trickles in minute streamlets through all parts of it to the sub-soil beneath, leaving open, during the suspension of its application, the myriad passages through which it has flowed, for the free admission and circulation of atmospheric air. No other practicable means is equally effectual to produce and preserve the soil's porosity.

DISSOLVES MANURES.

Then, too, it dissolves many of the fertilizers present in the soil, and thereby prepares them for timely reception by the crops growing upon its surface. As these can be received only in solution, if the requisite rain-fall be interrupted or abridged, in the absence of irrigation, plant-growth must inevitably languish.

IRRIGATION DISSEMINATES MANURES.

Water disseminates more evenly and thoroughly than can be done by any other instrumentality the fertilizer present in and upon the ground. Far greater than is appreciated is the loss resulting from imperfect incorporation of these with the soil to which they may have been applied. The wonderful results obtained in the use of sewage are largely due to a perfect distribution of assimilable plant-food throughout all its minute interstices. We may pulverize our manures ever so finely, and apply them with greatest care, even by finest drills, yet water will far surpass us in the work of their thorough dissemination.

MAINTAINS AN EQUABLE TEMPERATURE.

Water also aids greatly in the maintenance of an equable temperature of the soil, increasing its warmth during periods of cold, and reducing it in those of excessive heat. Thereby is secured to vegetation that evenness of development which does much to insure its highest perfection.

LENGTHENS THE SEASON.

Upon meadows, irrigation lengthens the growing season, and increases their productions, by causing an earlier start of the grass in spring, and by protecting it from the frosts of autumn. In our climate, it increases the ordinary period of vegetation four or five weeks. In fact, upon irrigated meadows, its growth will be active from the middle of April to the middle or last of November. It is to the grass-field what glass and shelter are to the grapery.

SECURES CONTINUOUS VEGETATION.

Crops often fail wholly or in part from interruptions in their growth. By preventing these, irrigation renders constant their development, and secures to the farmer maximum returns in years when a dependence upon the rain-fall alone would have left him but meagre ones.

IS IT PRACTICABLE IN NEW HAMPSHIRE?

Now, do you ask, Is irrigation practicable upon farms of so uneven surfaces as have most of ours? I answer, Yes. In the mountainous regions of Piedmont, nearly two hundred thousand (180,000) acres are under constant irrigation. It extends to the very shoulders of the Alps, and follows along the streams until the steepness of their channels makes them torrents. Away up in the bosom of the mountains, six thousand feet above the level of the sea, you may find it in successful operation.

Do you further ask, Have we the water requisite for irrigation? Not for universal irrigation, but enough for its practice upon hundreds of our farms, more or less of which may be found in every town of the state. How many considerable streams, unused for manufacturing purposes, one meets in going ten miles in any direction. How many sparkling brooks, gathered from streamlets upon the mountain's side, are frolicking down our pasture slopes, and winding through our meadows.* For what has God made

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*I have counted upon the county maps of our state, recently published by Comstock & Cline, nearly five hundred (472) rivers and brooks, considered of sufficient consequence to be noted and designated by their several names. If to these there be added the far more numerous streams of lesser magnitude, each of which has sufficient volume for irrigation, together with some five hundred lakes and ponds, it will at once be apparent that our water resources are ample for the prosecution of this improvement of our husbandry.—*J. B. W.*

these? Simply to aid in maintaining nature's great process of aquatic circulation between sea and air and land? Has he placed them there forever to laugh along their courses in idleness, mirroring at times the moon, and anon reflecting the sunlight? I trow not.

Let us awake, brother farmers, not merely to the exigencies of our occupation, but to the resources at our command, and remember that in more ways than one we may construe the words of our greatest dramatist, who has told us that

> "There is a tide in the affairs of men,
> Which, taken at the flood, leads on to fortune."

Thus far we have been accustomed to consider our lakes valuable only as reservoirs, and our streams as motive powers for manufacturing industries. Time, however, has been working vast changes in the conditions underlying the operations of these. The presence of water-power is no longer a necessity in their successful prosecution. Scores of our most important manufacturing towns and cities have very little, if any, of it. Steam affords so cheap and reliable a substitute that it is often preferred.

Hundreds of the waterfalls, to which has been attached high prospective value, will, in all probability, never find use as motors of machinery. Their true worth will be realized in the irrigating streams which they will eventually afford to an advanced and more profitable agriculture. In our humble belief, one of the most important of the several agencies, which are hereafter to secure the enlarged success which in the near future awaits this great industry, is irrigation.